J1.11

EXPERIENCE WITH THE PRINCE WILLIAM SOUND NOWCAST/FORECAST SYSTEM

Christopher N. K. Mooers* and Inkweon Bang*
University of Miami, Miami, Florida

and

Shari L. Vaughan#
Prince William Sound Science Center, Cordova, Alaska

1. Introduction

Prince William Sound (PWS), Alaska is a small (the order of 100 km by 100 km, with a mean depth of about 190 m; its two basins have maximum depths of about 500 m and 800 m) semi-enclosed sea that has two major ports (Hinchinbrook Entrance (HE) and Montague Strait (MS)), with sill depths of about 100 m, and a complex coastline deformed by numerous fjords and estuaries. Its circulation is quite variable (Vaughan, Mooers, and Gay, 2001) and is forced by vigorous tides, intense synoptic atmospheric forcing, strong seasonal atmospheric forcing, and seasonal snow melt, as well as throughflow from the variable Alaska Coastal Current (ACC) and influences of large-scale interannual and decadal variability of the North Pacific. PWS is extremely rich in living marine resources, and its marine ecosystem is quite variable and thought linked to the circulation variability. In the aftermath of the EXXON VALDEZ oil spill of 24 March 1989, marine ecosystem studies were initiated that led, in part, to the implementation (called PWS-POM) of the Princeton Ocean Model (POM) (Mellor, 1998) for the simulation of the 4-D ocean circulation of PWS. Subsequently, PWS-POM has been evolved into a first- generation, real-time, automated nowcast/forecast system (called PWS/NFS) for trajectory estimation of potential oil spills, and for use in larval transport and other ecosystem studies. PWS/NFS is ready for upgrading to a second-generation system in response to the experience gained to date. In this evolutionary process, several scientific questions have also been identified.

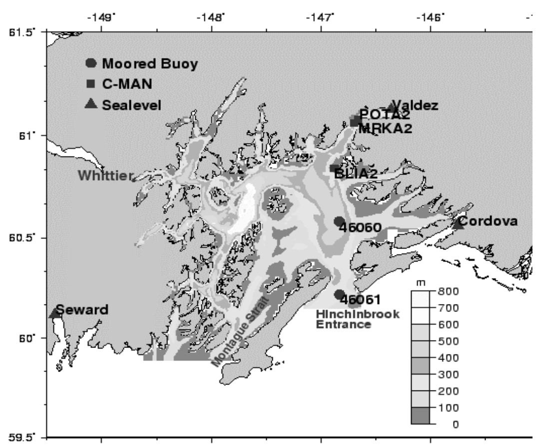


Figure 1. PWS topography and observing stations

2. PWS-POM

The major attributes of PWS-POM include: a ca. 1 km horizontal grid; 15 sigma (terrain – following) surfaces in the vertical; free surface and density stratification; the standard Mellor-Yamada level 2 ½ vertical turbulence closure scheme and the Smagorinsky hori-

*Christopher N.K. Mooers, Ocean Prediction Experimental Laboratory (OPEL), Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL 33149-1098; email:cmooers@rsmas.miami.edu

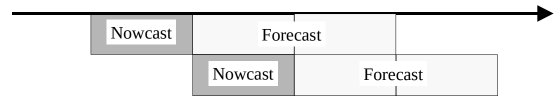
*Inkweon Bang Ocean Prediction Experimental Laboratory (OPEL), Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL 33149-1098; email: ibang@rsmas.miami.edu

#Shari L. Vaughan, Prince William Sound Science Center, Cordova, AK 99574; email: Vaughan@grizzly.pwssc.gen.ak.us

zontal turbulence closure scheme; realistic bottom topography and coastline; and realistic forcing as described below. A previous implementation was used to conduct a series of idealized sensitivity studies (Mooers and Wang, 1998). The present implementation has been validated by comparison with observations from the Sound Ecosystem Analysis (SEA) Program during the relatively data-rich year of 1996 (Bang, Vaughan, and Mooers, 2001). PWS-POM was forced by synoptic winds from a NDBC buoy in PWS, seasonal heating from the COADS climatology, a snowmelt runoff climatology (Simmons, 1996), and a monthly-varying estimate of net transport (and temperature and salinity profiles from historical data) at HE.The results of the comparison are mixed, and the discrepancies are attributable to uncertainties in the forcing functions and inadequacies in the model implementation strategy.

3. PWS/NFS

The first-generation PWS/NFS consists of PWS-POM together with an available set of variable forcing functions, independent verification data, and Web-based model output graphics. The present forcing functions are hourly NDBC buoy winds, COADS climatological heat flux, the Simmons snow melt climatology, and the eight most dominant diurnal and semidiurnal tidal amplitudes and phases (Foremanet al., 2000). Only radiation boundary conditions are applied at HE and MS; i.e., no ACC throughflow (net transport) is specified. The independent verification data consist of coastal sea level (tide gauge) and near-surface temperature at Valdez and Cordova and near-surface temperature at the NDBC buoy. On a daily basis, NDBC buoy winds, temperature, etc. are downloaded from NCEP/NWS and sea level and temperature from CO-OPS/NOS. The model is run for the past 24 hrs and then run ahead for 48 hrs with no winds. The verification activity reveals that the tides are well predicted, as is the seasonal warming of the upper layer. However, it also reveals that some of the synoptic scale variability in sea level is not captured, presumably due to deficiencies in representing the influence of regional scale atmospheric forcing at the open boundaries. The suite of Web-based graphical products includes maps and transects of several variables, animations of surface currents and winds, and representative surface particle trajectories.



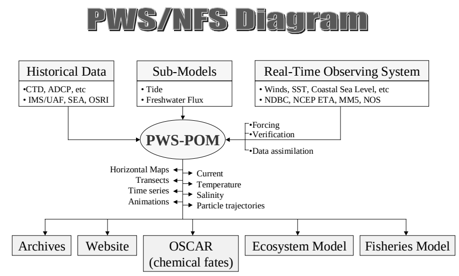


Figure 2. PWS/NFS diagram

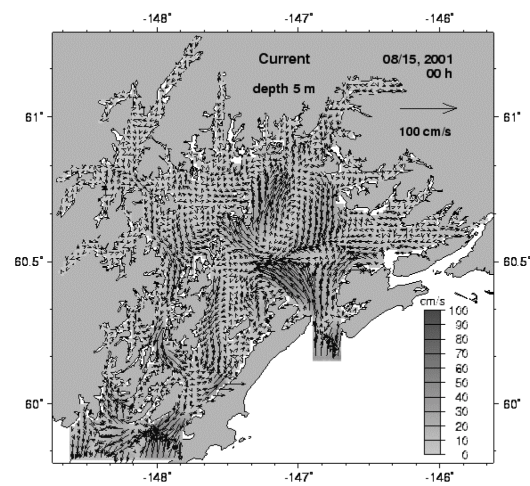


Figure 3. Forecast current field at 5 m depth

4. Lessons Learned

First, both NCEP/NWS and CO-OPS/NOS have become reliable, user-friendly sources of high-quality, real-time data via the Web, though there can be episodes with data gaps. (Fortunately, there is more than one NDBC buoy in the vicinity so there is robustness if one fails.) Second, the spatial variability of the winds may be a very significant factor affecting PWS/NFS accuracy, especially for surface currents and surface drift, and especially in the presence of the complex coastal orography that encompasses PWS. Preliminary assessment of NCEP's operational mesoscale numerical weather predictions, made with the Eta model (about 32 km resolution), are very promising. Hence, the Eta model will become a source of atmospheric forcing information for the second-generation PWS/NFS; it also has the vital attribute of providing forecasts out to 60 hrs as well as nowcasts. However, the width scale of the fjords and estuaries of PWS suggest that a meso-grid of 10 km or finer will be needed; thus, it is anticipated that a high-resolution, research-mode mesoscale atmospheric prediction system will be implemented for PWS in the near future. Third, based on various indications (including a process study of the interactions of PWS and the Alaska Shelf (Bang and Mooers, 2001)), the PWS circulation is very sensitive to the flow and mass fields at HE and MS, which, in turn, are sensitive to wind, ACC stratification and strength, etc. However, it is very difficult to observe the space-time variability of the flow and mass fields there with sufficient vertical and horizontal resolution and span, especially in real-time. Thus, it is essential in the second-generation PWS/NFS to switch to a larger domain and let the model's internal dynamics determine the flow and mass fields at HE and MS. The larger domain will also admit the use of alternative datasets; e.g., satellite altimetric sea surface heights and scatterometric surface winds, plus flow and mass fields on its open boundaries from basin-scale nowcast/forecast models. Fourth, based on use of the SEA data in 1996, Eulerian time series of flow and mass fields over the water column, and Lagrangian upper-layer trajectories, are invaluable for model validation and presumably verification. Therefore, there would be high value in establishing a modest network of oceanic, water-column, real-time observing elements (placed in strategic locations, including HE and MS, inside and outside PWS) on a continuing basis, coordinated with periodic deployments of satellite-tracked, near-surface as well as upper-layer drifters. Fifth, based on the strong influence of the snowmelt and the buoyancy-driven ACC, a hydrological model (e.g., as an upgrade to Simmons (1996)) should be run in an operational-mode. Sixth, based on the high correlation of coastal oceanic and atmospheric time series both up-coast and down-coast a few hundred km from PWS with those inside PWS, the PWS dynamical system is connected to the regional dynamics of the Alaska Shelf on the synoptic and intra-seasonal time scales. These relationships provide a basis for a data assimilation strategy designed to improve estimates of open boundary conditions.

Among the myriad of scientific issues that have arisen in this research, a few standout as fundamental to the scientific underpinnings of PWS/NFS: (1) the dynamical controls on the PWS throughflow (through HE and PWS) or, similarly, the dynamical controls on the exchange between PWS (through HE and MS) and the Alaska Shelf; (2) the nature of the ventilation process in PWS, given the evidence for strong transient divergences and over-turning circulation; and (3) the exchange rates and pathways throughout PWS, including the numerous fjords and estuaries and re-circulating links with the Alaska Shelf circulation. Other scientific issues include the impact of the vigorous tidal circulation on the mean flow and exchange processes. Technical issues include how to efficiently treat both tidal forcing and sub-tidal frequency forcing on open boundaries.

5. Acknowledgements

This research is sponsored by the Oil Spill Recovery Institute (OSRI) of Cordova, Alaska. Michael Foreman is thanked for providing tidal coefficients in advance of publication.

6. References

Bang, I., Vaughan, S. and C.N.K. Mooers (2001). Initial Steps toward Validation of a Seasonal Cycle Simulation for Prince William Sound Circulation (Flow and Mass) Fields. (in preparation).

Bang, I. and C.N.K. Mooers (2001). The Influence of Several Factors Controlling the Interactions between Prince William Sound, Alaska and the Northern Gulf of Alaska. J. Phys. Oceanogr. (under revision)

Foreman, M.G.G., R.E. Thompson, and C.L. Smith (2000). Seasonal Current Simulations for the Western continental Margin of Vancouver Island. J. Geophys. Res, 105: **19**, 665-19, 698.

Mellor, G. L. (1998). Users'Guide for a Three-Dimensional, Primitive Equation, Numerical Ocean Circulation Model. Program in Atmos. and Ocean Sci., Princeton University, 41pp.

Mooers, C. N. K. and J.Wang (1998). On the Implementation of a Three-Dimensional Circulation Model for Prince William Sound, Alaska. Cont.Shelf Res., **18**: 253-277.

Simmons, H. L. (1996). Estimation of Freshwater Runoff into Prince William Sound using a Digital Elevation Model. M.S. Thesis, University of Alaska, Fairbanks, Alaska, 78 numb. leaves.

Vaughan, S.L., C. N. K. Mooers, and S. M. Gay III (2001). Physical Variability during the SEA Program (1994 to1998) in Prince William Sound. Fisheries Oceanography (in press).